Pest Management Grants Final Report

Contract Number: 98-0276

Project Title: Rotations with Broccoli – A Sustainable Alternative to Soil Chemical Fumigants

Principal Investigators: Dr. K. V. Subbarao, University of California, Davis, Salinas
Dr. F. N. Martin, USDA-ARS, Salinas
Dr. K. G. Shetty, University of California, Davis, Salinas

Address: UC Davis, 1636 E. Alisal Street, Salinas, CA 93905

Preparedfor California Department of Pesticide Regulation

Date: March 28, 2000

Rotations with Broccoli: A Sustainable Alternative to Soil Chemical Fumigants

TABLE OF CONTENTS

Summary

The effects of vegetable crop rotations and residue amendment on strawberry plant diameter, disease severity, and marketable yield were compared with methyl bromide+chloropicrin fumigation, at two sites during 1997-98 and at one site during 1998-99. The Watsonville site had moderate level of background *Verticillium dahliae* inoculum (10 microsclerotia g^{-1} soil) and the Spence field site plots had no detectable microsclerotia. The rotation scheme consisted of two successive crops of broccoli, cauliflower and lettuce followed by strawberry at the Spence field site. At the Watsonville field site, similar rotation scheme was followed except that brussels sprouts was planted instead of cauliflower. At Watsonville, after four crops of vegetables and one crop of strawberry, the numbers of *V. dahliae* microsclerotia in broccoli plots were consistently low, while the lettuce plots were a potential reservoir of microsclerotia. At both sites broccoli plots had higher strawberry plant diameter than other treatments. The disease severity in broccoli rotation plots was the lowest at Spence, and at Watsonville, broccoli rotation treatments had the least disease severity next only to fumigated plots. At Watsonville, during the final harvest, yield loss was 23% lower in broccoli rotation treatment and 39% lower in lettuce rotation treatment compared with the standard fumigation treatment. No significant difference in yield among treatments was observed at Spence in the absence of Verticillium wilt during 1997-98 trial. During 1998-99 trial at Spence, again no significant difference in yield was observed among the vegetable rotation treatments. Under moderate disease pressure, broccoli rotation has the potential to be a feasible alternative for reducing Verticillium wilt severity in strawberry.

INTRODUCTION

Strawberry is an important horticultural crop in the state of California, with an annual farm gate value of over $700 million. Pre-plant soil fumigation of strawberry fields with methyl bromide is the prevailing production practice to control weeds, soilborne pathogens, and nematodes. The imminent loss of methyl bromide due to environmental concerns has accelerated the search for sustainable alternatives to methyl bromide. Among the soilborne pathogens, Verticillium wilt is the most important as it causes death of plants. There is no resistance against Verticillium wilt in currently grown cultivars. *Verticillium dahliae* the causal agent of wilt disease has a wide host range and is distributed in most California agricultural soils. The microsclerotia of *V. dahliae* can survive in the soil for many years. Strawberry cultivars are highly susceptible to *V. dahliae* infection; as few as 2 microsclerotia per gram of soil can result in 100% disease incidence.

In some production systems crop rotation can be an economically viable means of reducing soilborne propagules of *V. dahliae* and yield losses from wilt disease. Broccoli is the most promising rotation crop with many advantages. Broccoli is not susceptible to Verticillium wilt, is grown extensively in the coastal valleys and broccoli residue has been shown to be detrimental to *V. dahliae* propagules in soil. Previous field trial results have consistently demonstrated the effectiveness broccoli rotation and residue amendment for Verticillium wilt management in cauliflower. In the current study, the feasibility of using broccoli rotations as an alternative to chemical fumigants in strawberry production system was tested. Specific objectives of this project were to study the effects of strawberry rotations with broccoli, brussels sprouts, cauliflower, and lettuce on strawberry yield, disease incidence and on soil populations of pathogen propagules.

MATERIAL AND METHODS

Experimental site. The field experiments on vegetable crop–strawberry rotations were conducted during 1997-98 at two locations and during 1998-99 at one location. Experimental plots were located at Monterey Bay Academy (MBA), near Watsonville, CA, on an Elder sandy loam soil and at the Spence field site, Salinas, CA on a Chualar loam soil. This is the first time strawberries have been planted at this location on the Spence field site. At both locations, commercial growers managed strawberry and vegetable productions. Inoculum density was moderate to high at the MBA site with an average of 10 *V. dahliae* microsclerotia g^{-1} soil but below detectable levels for the Spence site. Both locations were naturally infested with other soilborne strawberry root pathogens (*Pythium*, binucleate *Rhizoctonia*, and *Cylindrocarpon* spp.)

Treatments and experimental design. There were three rotation treatments at each location. The crops were planted in the following sequence 1) lettuce-lettuce-strawberry; 2) broccoli-broccoli-strawberry; and 3) brussels sprouts-strawberry (MBA only) or cauliflower-cauliflower-strawberry (Spence only). The treatments were laid out in a randomized complete block design with four replications. At MBA, the individual plots consisted of two single beds of 7.6-m length and at the Spence location there were eight single beds of 9-m length. Standard grower production practices were followed during each crop cycle. The rotational crops were transplanted during mid-April and the planting cycles were timed to include two rotational crops of lettuce, broccoli, or cauliflower but only one brussels sprouts cropping cycle.

After harvest, all crop residues were flail shredded, air dried on the surface for a minimum of two days and incorporated into the soil using a rototiller. Four weeks after incorporation, the beds in all plots were reworked for the next crop cycle. Strawberries (cv. Selva) were planted during November in all plots (including a replicated plot fumigated with methyl bromide+chloropicrin (67+33) for comparison with rotation treatments). Again standard grower production practices were followed during the strawberry crop cycle.

Soil samples to determine the densities of *V. dahliae* propagules were collected at the beginning and at the end of rotational crop, and every month after planting strawberry. Samples were assayed using the modified Anderson sampler technique by plating soil on the semi-selective NP-10 medium.

Plant canopy, yield and disease determinations. To determine the relative effects of different rotation treatments, plant growth during establishment was monitored by recording plant canopy diameter of 30 plants in each replication every month. Twenty plants per plot were visually rated for Verticillium wilt severity to monitor disease progress every other week from May. The disease severity estimate was done on the scale of 0 to 8, where 0 = healthy plant, 2 = moderately stunted, 3 = moderately stunted, slight rosette of dead leaves, 4 = moderately stunted, moderate rosette, 5 = significantly stunted, slight rosette, 6 = significantly stunted, moderate rosette, 7 = significantly stunted, significant rosette, 8 = dead plant. Yield data for marketable yield and culls were obtained in the plots once a week at MBA and twice a week at Spence site.

Data analysis. Differences between treatments for strawberry plant canopy diameter, disease severity and marketable strawberry yield were determined by analysis of variance, and means were compared by the least significant difference test ($P \leq 0.05$). Numbers of microslcerotia in each treatment were expressed as microsclerotia g^{-1} of dry soil. Means and the corresponding standard errors were computed for each treatment and sampling time. Repeated measures analysis of variance was used to test disease severity from different treatments recorded over time. All analyses were done using SAS (release 6.12 ed., SAS Institute, Cary, NC).

RESULTS

In 1997-98, at the MBA site, the soil inoculum levels of *V. dahliae* were moderate at the start of the experiment. However, the inoculum levels were affected by the vegetable-strawberry crop rotation (Fig. 1). The lettuce rotation treatment was more conducive for build up of inoculum, with upper ranges of 10-17 microsclerotia g^{-1} soil being more frequent. Whereas in brussels sprouts treatment the inoculum build up was moderate to low and the numbers were not high as in lettuce treatment. Broccoli rotations reduced the inoculum significantly and the inoculum levels remained consistently low throughout the sampling period. No detectable microsclerotia were present in the Spence field soils during the both growing seasons.

At both locations, higher strawberry plant canopy diameter was recorded in broccoli rotation treatment (Table 1 and Fig. 6). Plants grown in lettuce treatments at both the locations had significantly lower plant diameter than the rest of the treatments.

The repeated measures analysis of variance indicated that the rotation treatments had a significant ($P \leq 0.05$) effect on the strawberry disease severity rating during all of the observation points at both locations (Figs. 2,3 and 7). At MBA, strawberry plants grown in lettuce rotation treatment plots had the highest disease severity rating, about 25% - 27% higher

than in the broccoli treatment. At Spence, plants grown in broccoli rotation treatment showed the lowest disease severity rating among all the treatments, and at MBA, the broccoli treatment disease severity was next only to that of methyl bromide and chloropicrin control. Strawberry plants in broccoli rotation treatment showed a consistently lower disease severity than in the rest of the rotation treatments during all of the six observation dates. Petioles from diseased plants from MBA site when plated on NP-10 medium yielded *V. dahliae*. The diseased plants from Spence site did not yield *V. dahliae*, indicating other soil borne pathogens were responsible for growth and yield reductions. During the 1998-99 season at Spence, the disease severity ratings were low and diseases observed were mostly powdery mildew and other non-Verticillium soilborne pathogens. However, towards the end of the season a few diseased plants yielded *V. dahliae*. The emergence of Verticillium wilt in the plots with no initial detectable soil inoculum may have been due to a build up of inoculum in the presence of susceptible host.

Methyl bromide and chloropicrin fumigation produced the highest marketable strawberry yields obtained in both test locations (Figs. 4 and 5). Yield at final harvest at Spence was not significantly different among rotation treatments (Fig. 4 and 8). However, at MBA, the broccoli treatment plot marketable yield was significantly higher than in lettuce treatments. The yield was 23% lower in broccoli plots and 39% lower in lettuce plots compared to the fumigated control. **During the 1998-99 trial at Spence field site the methyl bromide and chloropicrin fumigation failed to produce higher strawberry yield compared to the vegetable rotation plots. Faulty fumigation reduced the effectiveness of the applied fumigant.**

DISCUSSION

The results from these field studies demonstrated the significant effects of different vegetable crop rotation on successive strawberry plant growth, yield, Verticillium wilt severity and on *V. dahliae* propagules in soil. Among the vegetable crops tested, rotations with broccoli had the most beneficial effects on strawberry growth and yield at both locations. The beneficial effects of broccoli rotation were further substantiated by the reduced yield loss both in the presence of *V. dahliae* and in the presence of other soilborne fungal pathogens. The beneficial effects of broccoli rotation in management of soilborne fungal diseases previously have been reported mostly with short duration crop plants. Therefore, it is important to recognize the sustained beneficial effects of broccoli rotation observed throughout the extended periods of strawberry production.

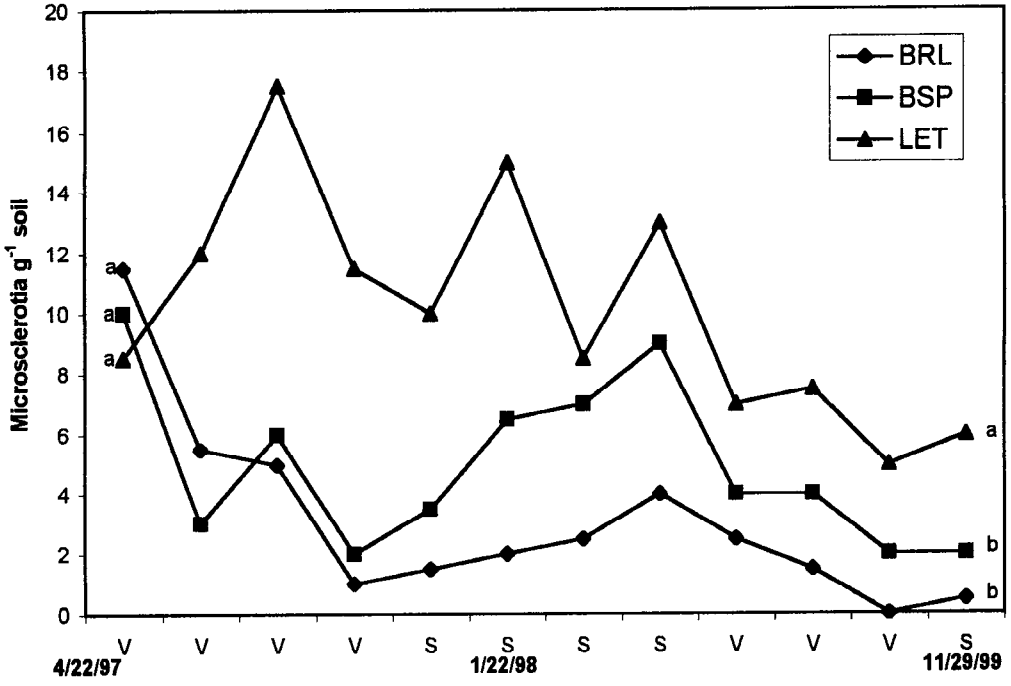
According to the cost-benefit analysis projections (Appendix) on the basis of one season trial of broccoli/strawberry crop system, the broccoli–strawberry rotation promises to be as an economically viable option under moderate Verticillium wilt pressure. At the Spence site, the only limitation observed was the sporadic occurrence of weeds under partial bed plastic mulch, and we expect the problem to subside with the successive rotations. At MBA, where the disease pressure was moderate to high, the limitation with plot size is being addressed with larger plot sizes for experimentation during the current year. The experiments are being repeated at both locations this year.

The details of field experiments on use of vegetable rotations as non-chemical alternatives to methyl bromide fumigant and the results obtained were discussed with strawberry growers and researchers during field days, regional growers meetings and scientific meetings.

SUMMARY AND CONCLUSIONS

In the strawberry production system, feasibility of vegetable crop rotations was tested as non-chemical and environmentally safe alternative to chemical fumigant methyl bromide. At the field sites with contrasting Verticillium wilt pressure, broccoli rotations and residue amendment resulted in better plant growth and marketable yield, lower yield loss, low disease severity and reduction in *V. dahliae* population in soil. For strawberry production in California central coast, under moderate inoculum levels broccoli rotation can be an effective and compatible management practice for reducing Verticillium wilt severity.

Fig.1. Effects of crop rotation[1] on inoculum densities[2] of *Verticillium dahliae* at MBA

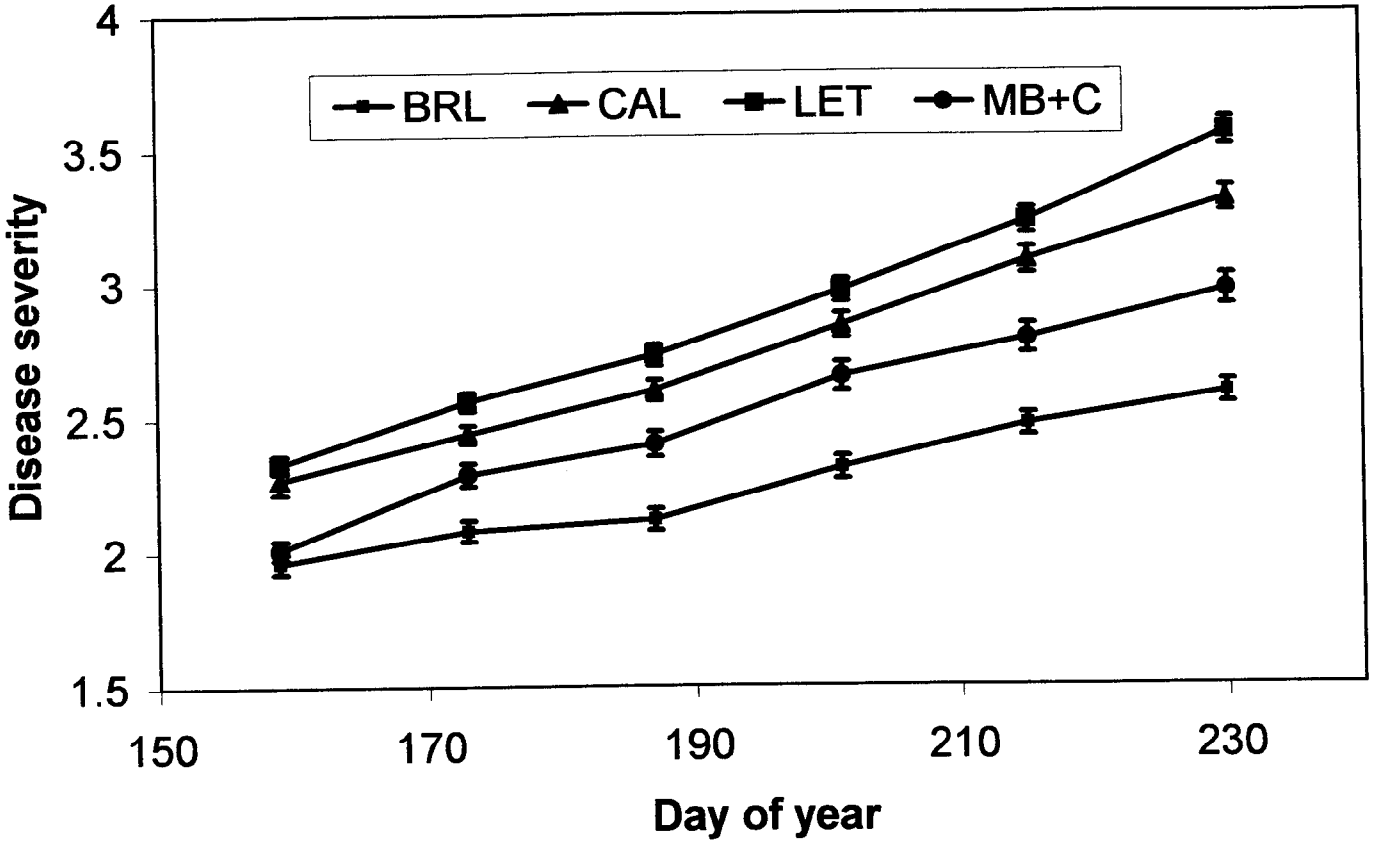


[1] BRL=Broccoli, BSP=Brussels sprouts, LET=Lettuce

[2] Soil samples taken during the course of the study in different rotation treatments (V=vegetable, S=Strawberry)

Means with same letter are not significantly different according to an LSD test ($P \leq 0.05$)

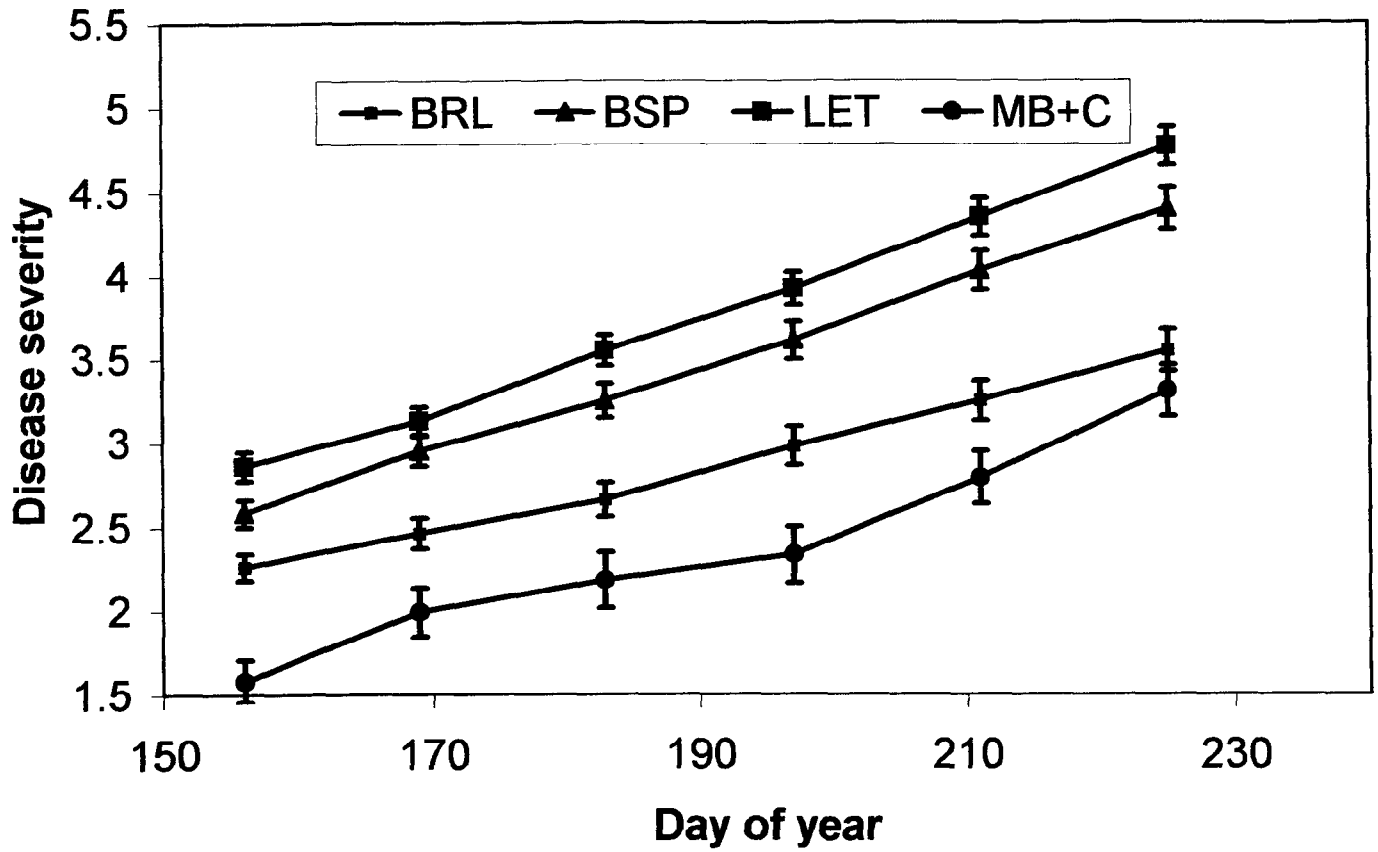
Fig. 2. Effects of rotation and fumigation on the strawberry disease severity* in 1998 at Spence, CA



*Disease rating observations are from 9 month old standing crop

*Disease rating scale 1=healthy plant, 2=moderately stunted, 3=moderately stunted, slight rosette of dead leaves, 4=moderately stunted, moderate rosette, 5=significantly stunted, slight rosette, 6=significantly stunted, moderate rosette, 7=significantly stunted, significant rosette, 8=dead plant

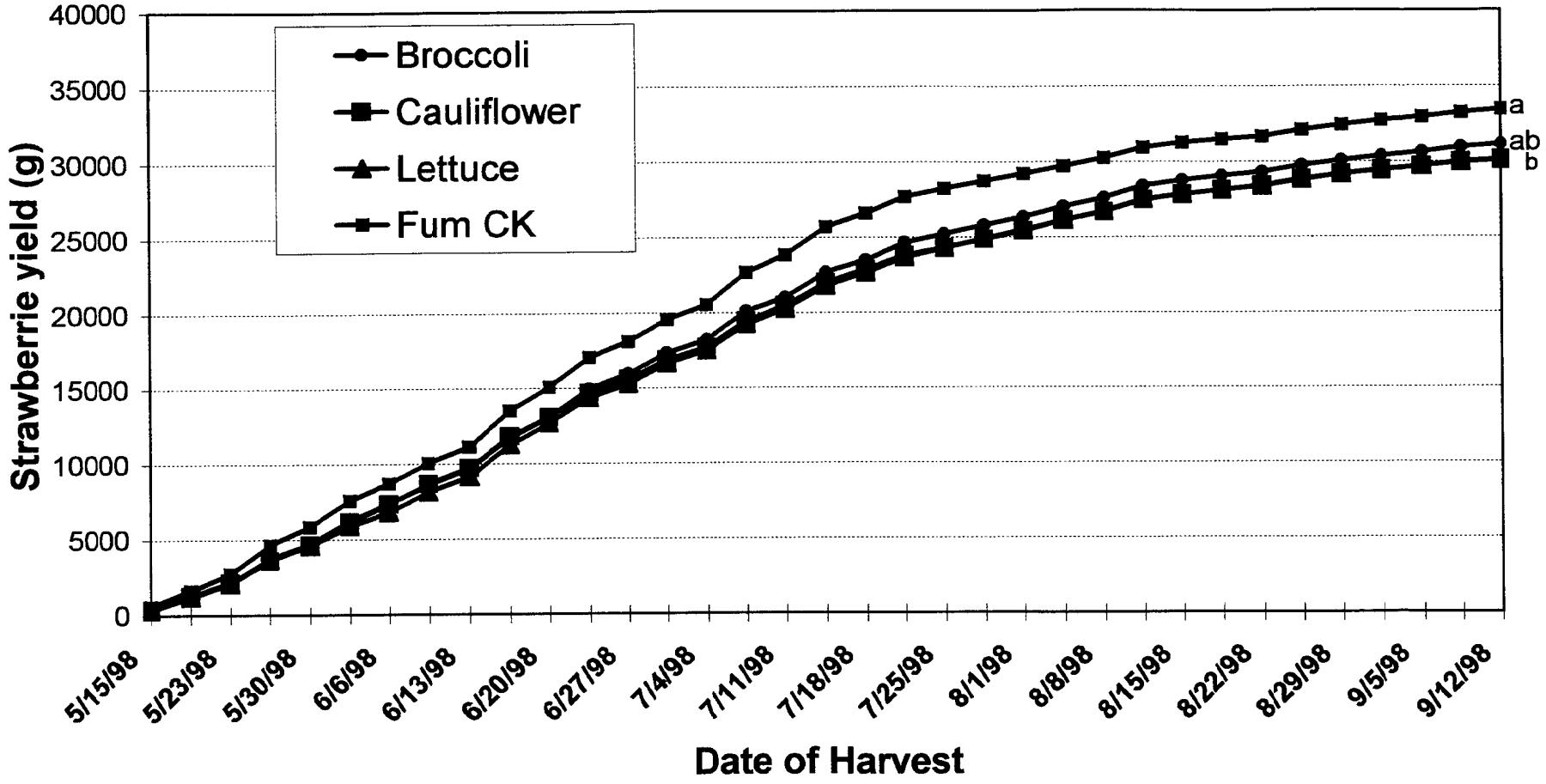
Fig. 3. Effects of rotation and fumigation on the strawberry disease severity* in 1998 at MBA, CA



*Disease rating observations are from 9 month old standing crop

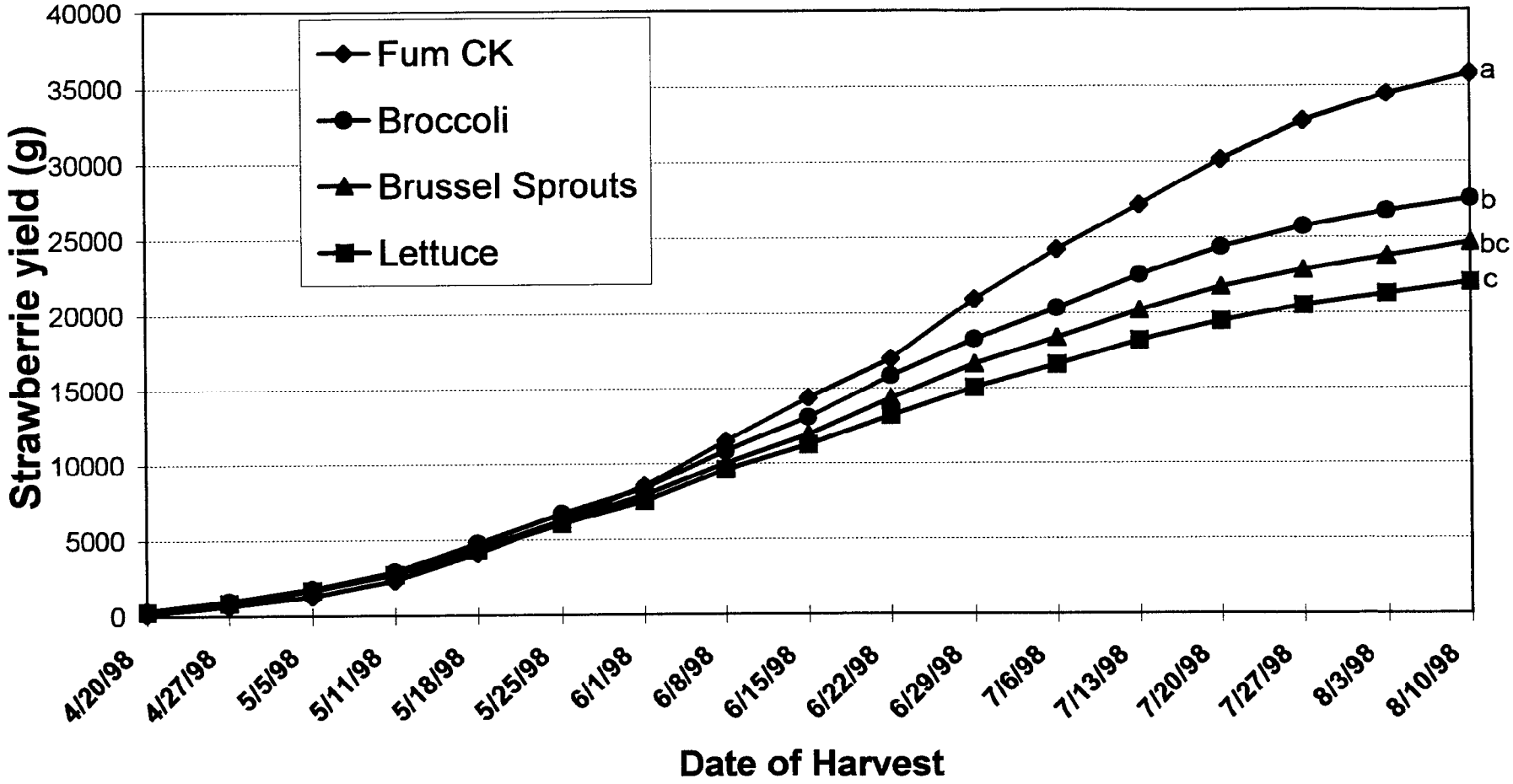
*Disease rating scale 1=healthy plant, 2=moderately stunted, 3=moderately stunted, slight rosette of dead leaves, 4=moderately stunted, moderate rosette, 5=significantly stunted, slight rosette, 6=significantly stunted, moderate rosette, 7=significantly stunted, significant rosette, 8=dead plant

Fig. 4. Cumulative Market Yield of strawberry at Spence during 1998 in fumigated and various rotation treatments.



Means with the same letter are not significantly different according to an LSD test ($P \leq 0.05$).

Fig. 5. Cumulative Market Yield of strawberry at MBA during 1998 in fumigated and various rotation treatments



Means with the same letter are not significantly different according to an LSD test ($P \leq 0.05$).

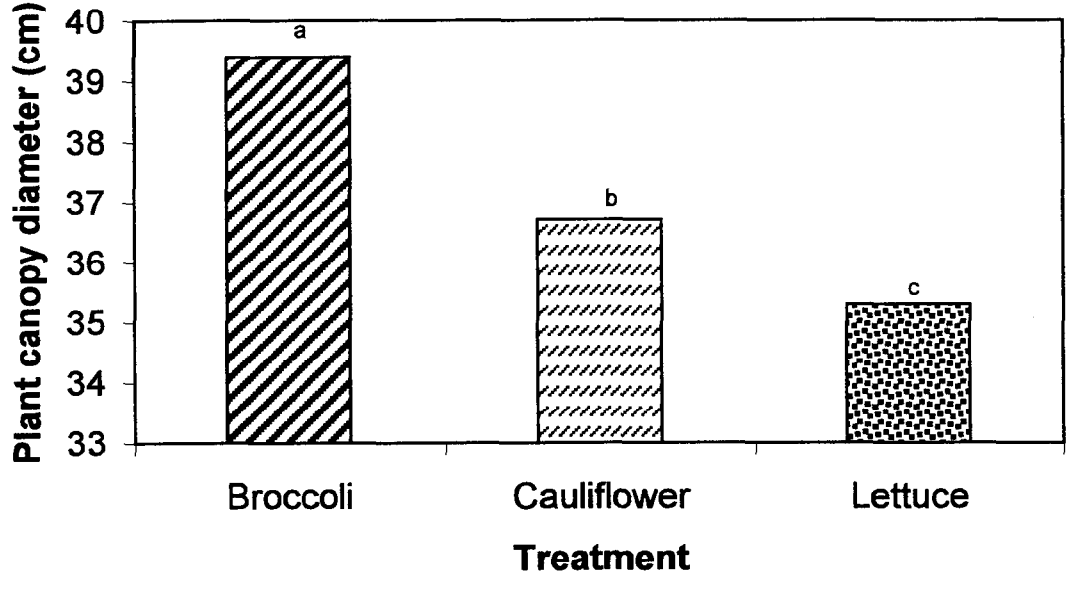
Table 1. Effect of crop rotation and residue incorporation on strawberry plant canopy diameter[1] at Spence and Monterey Bay Academy sites.

Treatment	Spence field	MBA field
Fumigated check	30.70 b[2]	27.67 b
Broccoli	31.33 a	29.87 a
Brussels sprouts		28.25 b
Cauliflower	29.17 c	
Lettuce	28.57 d	25.90 c

[1] Plant canopy diameter observations recorded 5 month old standing crop
Means are from 30 plants per replication

[2]Means with the same letter are not significantly different according to an LSD test ($P \leq 0.05$)

Fig.6. Effects of crop rotation[1] on strawberry plant canopy diameter[2,3] at Spence 1999

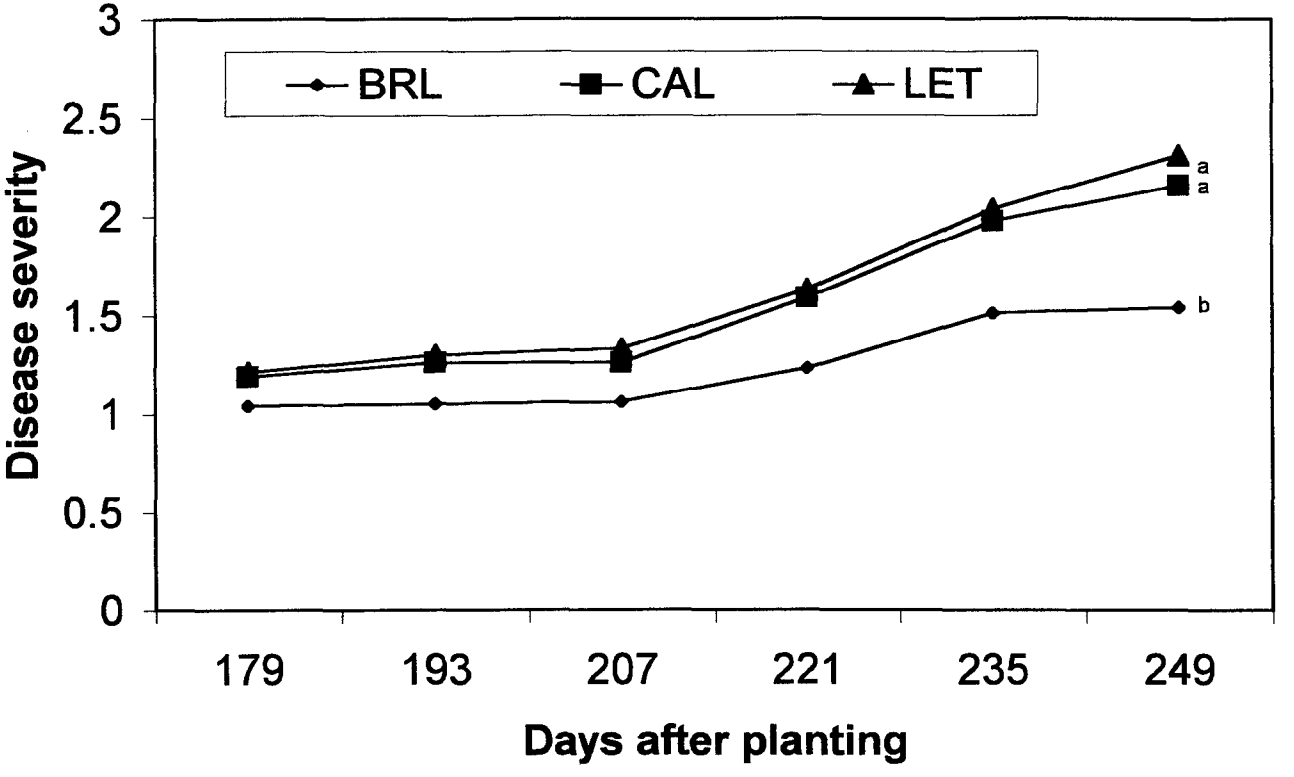


[1] The efficiency of fumigation with methyl bromide+chloropicrin was low and hence data from control plots are not presented.

[1] Plant canopy diameter observations recorded on 6 month old standing crop Means are from 80 plant per replication

[2] Means with same letter are not significantly different according to an LSD test ($P \leq 0.05$)

Fig. 7. Effects of rotation[1] on the strawberry disease severity* in 1999 at Spence, CA

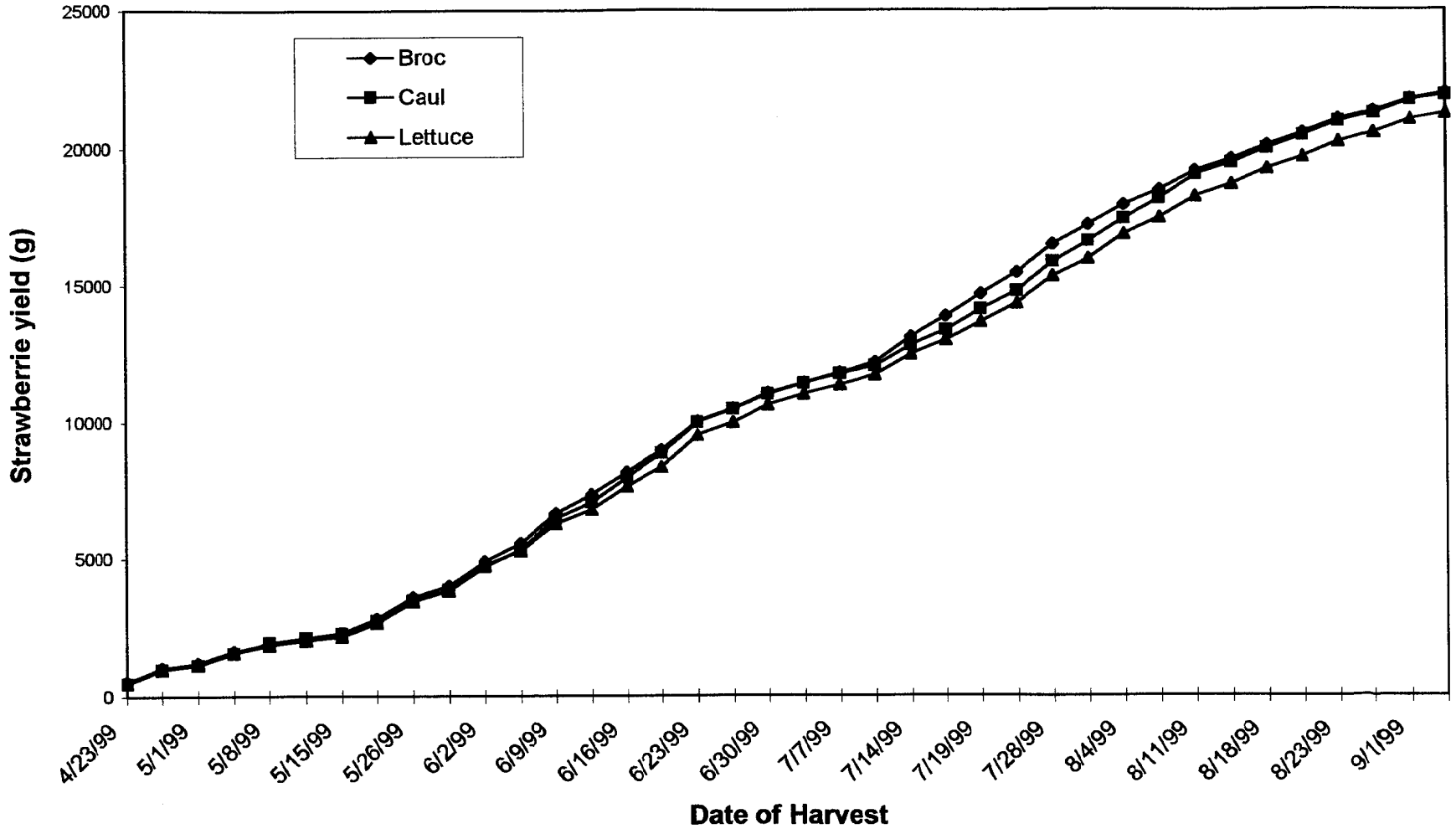


Means with the same letter are not significantly different according to an LSD test ($P \leq 0.05$).

*Disease rating scale 1=healthy plant, 2=moderately stunted, 3=moderately stunted, slight rosette ofdead leaves, 4=moderately stunted, moderate rosette, 5=significantly stunted, slight rosette,6=significantly stunted, moderate rosette, 7=significantly stunted, significant rosette, 8=dead plant.

[1] The efficiency of fumigation with methyl bromide+chloropicrin was low and hence data from control plots are not presented.

Fig.8. Cumulative Market Yield of strawberry at Spence during 1999 in the three rotation treatments[1].



[1] The efficiency of fumigation with methyl bromide+chloropicirin was low and hence data from control plots are not presented

Comparative strawberry and broccoli production system average costs and returns (per acre). Figures based on grower interview and observations from field trials at two sites.

1. **Strawberry with methyl bromide fumigant (1 year crop cycle)**

Total cost	$32,785
Total Yields	5,200 trays
Total value (@$7.125 per tray	$37,050
Return	$4,265

2. Broccoli (3 month crop cycle)

Total cost	$1,900
Total Yields	850 cartons
Total value (@$6.5 per carton	$5,525
Return	$3,625

3. **Strawberry without chemical fumigant (1 year crop cycle)**

Total cost	$32,085 (Partial beds plastic mulch)
	$31,185 (Full bed plastic mulch)
Deduct methyl bromide cost $1600 Add weeding cost $900 (Partial bed plastic mulch) Deduct weeding cost $900 (Full bed plastic mulch)	
Total Yield	3,380 to 2,600 trays
Yield loss due to Verticillium wilt at MBA ranges from 35% to 50% without chemical fumigant	
Total value (@$7.125 per tray)	$24,083 to $18,525

Return	Loss of $8,002 to $13,560 (partial bed mulch) Loss of $7,102 to $12,660 (full bed mulch)

4. Two Broccoli rotation crops and one Strawberry crop

Strawberry cost	$32,085 (Partial bed mulch) $31,185 (full bed mulch)
Deduct methyl bromide cost $1600 Deduct weeding cost $900 (data suggest that broccoli may also reduce weed populations)	
Broccoli cost (Two crops)	$3,800
Total cost	$35,885 to 34,985
Strawberry Yields	3,900 trays
Average yield loss due to Verticillium wilt 25% with Broccoli rotation (MBA field data).	
Strawberry value (@$7.125 per tray	$27,787
Broccoli yields (Two crops)	1700 cartons
Broccoli value (Two crops) @$6.5 per carton	$11,050
Total value	$38,837
Return	$2,952 to $3,852